In Situ X-Ray Studies of MOCVD $Pb(Zr,Ti)O_3$ Growth

Scientific Achievement

Utilizing synchrotron x-ray techniques for *in situ* probing of materials processing in real time, we have observed strain-coupled composition (Zr/Ti) variation during the chemical vapor deposition of $Pb(Zr,Ti)O_3$ (PZT) during strain relaxation. While strain-coupled composition variation has been observed in semiconductor systems, it has not been observed in complex oxide systems. In particular, PZT thin films are an attractive material for future nanoscale electronics, sensors, and micromechanical actuators. Previous studies on $PbTiO_3/SrTiO_3$ found ferroelectricity for films with thickness as small as 1.2 nm and suggested that this could represent a fundamental size limit. In the alloy $PbTiO_3$-$PbZrO_3$ system, the growth of homogeneous planar ultrathin films becomes a great challenge due to the strong interplay between the strain, composition and morphology. Such strong coupling can greatly influence ferroelectric behavior and modify the practical limits of ferroelectricity in such system.

Significance

This work gives us new understanding of the competing effects of strain, composition, depolarizing field, and surfaces on ferroelectricity in ultrathin films, and provides the basis for design of devices that capitalize on the unique properties of these materials. Future directions for study include understanding the ferroelectric polarization distribution in PZT films as both strain and composition varies across the film thickness. Elastic strain and its relaxation kinetics are expected to be strong functions of temperature and growth kinetics. What are the practical limits of property enhancement, optimizing both elastic strain development and composition control? Using synchrotron x-rays to monitor strain and ferroelectricity in real time during film growth and processing will be key to understanding these effects. With the precise control of growth (down to one atomic layer resolution) using synchrotron scattering, we can also engineer the ferroelectric polarization distribution in superlattice structures consisting of PZT layers with varying Zr/Ti ratio and strain state. Future studies using the CNM x-ray nanoprobe will investigate the possible lateral composition segregation in ferroelectric oxide thin films.

Performers

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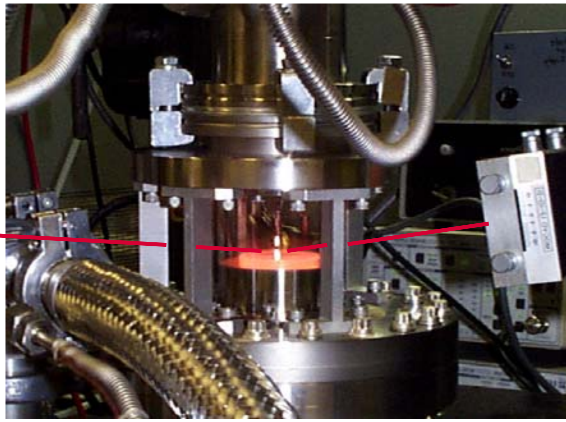
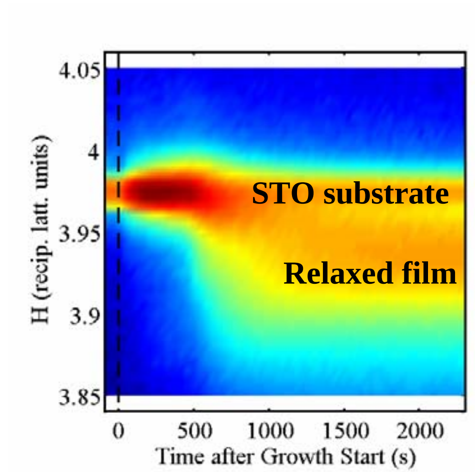
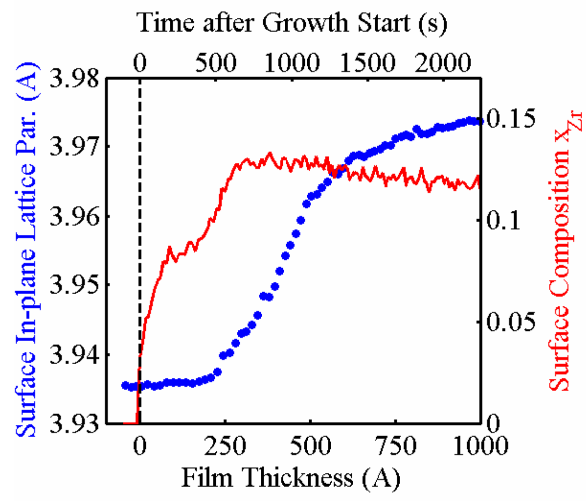
X-ray



Chemical Vapor Deposition Chamber

In situ monitoring of strain relaxation and composition variation during MOCVD growth using synchrotron x-ray





Future Directions

- **Probe the ferroelectric polarization distribution of films with strain and composition non-uniformity.**
- **Investigate the practical limit of ferroelectricity in $Pb(Zr,Ti)O_3$ alloy oxide system.**
- **Study the lateral segregation in $Pb(Zr, Ti)O_3$ using CNM nanoprobe.**

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